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THE EFFECT OF MODERATE ALTITUDE UPON HUMAN GASTRIC EMPTYING TIME

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FOREWORD

This work was conducted in the Aero Medical Laboratory, Research Division, Wright Air Development Center, under the research and development project identified by RDO No. 696-80, In-Flight Ration Requirements, with Everett Shocket, Captain, USAF (MC), and Miss Margaret M. Jackson acting as project engineers.

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ABSTRACT

The effect of moderate altitude upon the motility of the human stomach has been studied in volunteer subjects. The time required for complete gastric emptying of a standard radiopaque meal has been determined by serial roentgenograms. No significant difference in human gastric emptying time was detected between the experiments conducted at ground level and those conducted at moderate altitude. (12,500 feet to 15,000 feet).

PUBLICATION REVIEW

Manuscript copy of this report has been reviewed and found satisfactory for publication.

FOR THE COMMANDING GENERAL:

Robert H Blount
ROBERT H. BLOUNT
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CONTENTS

TABLES

ILLUSTRATIONS

INTRODUCTION

To aid in the formulation and substantiation of feeding requirements for Air Force personnel during flight operations, an evaluation has been undertaken of the effect of flight conditions upon gastrointestinal function. This is a report of ~~a study~~ dealing with the interrelationship of moderate altitudes and human gastric emptying. It was found that the stomach emptying time at ground level (Dayton, Ohio, 830 feet) was no different from that at moderate altitudes (12,500 feet and 15,000 feet). The altitudes selected are consonant with those experienced daily by USAF personnel.

The only related prior work is that of Van Liere and co-workers[1,2] who demonstrated in dogs (1933)[1] and in men (1935)[2] a delay in gastric evacuation at simulated altitudes in excess of 8,000 feet. In those pioneer studies, however, it was necessary to remove the subjects from the chamber periodically for fluoroscopy. It was thought that, if such a study could be conducted free of periodic ascent and descent, definitive information might be obtained that would assist in determining the nature of in-flight digestion and in delineating flight feeding requirements.

SECTION I - PLAN

The gastric emptying times of volunteer subjects following a standard meal were determined at ground level and at moderate altitude. The addition of barium sulfate to the test meal made it radiopaque. The progress of the meal (food plus barium) through the subject's gastrointestinal tract was traced by serial roentgenograms. Such a direct determination of gastric evacuation was deemed preferable to the indirect methods that involve intragastric balloons or intragastric tubes. Balloons primarily reflect the intensity of intralumenal pressure resultant from the activity of the fundic and the antral musculature. The nature of pyloric activity may remain unknown; propulsive contractions may not be differentiated from possible pure segmenting contractions. Intragastric tubes, on the other hand, permit only fractional aspiration of gastric contents as an indirect approximation of gastric emptying time. In addition, the presence of any exogenous tubing in the stomach constitutes an unknown, unnatural stimulus of constant mechanical force, whereas, a meal provides a natural, progressively diminishing, endogastric mechanical and chemical stimulus. For most people gastric intubation of any sort constitutes a distinctly unpleasant experience with nausea and vomiting not uncommon consequences. Such disturbances clearly preclude reliable studies.

While barium sulfate ingestion is not entirely free of criticism it is, nevertheless, well tolerated by many untrained persons. In the experiments reported here the barium sulfate constituted a mere 15% (by weight) of the entire meal and only subjects who tolerated the mixture well were continued. Barium sulfate is of high specific gravity and is not a physiological aliment. The emptying time, therefore, of a mixture of barium and food may perhaps differ somewhat from that of food alone. Determination of the latter, however, is not possible with currently available techniques and the small concentration of barium in these experiments militated in favor of but a slight discrepancy. Throughout this study absolute figures were not essential; of importance, rather, was the relative difference in gastric response to the test meal at altitude compared to that at ground level.

The use of a pressure-resistant, but roentgen-penetrable, plastic window in the door of the decompression chamber made it possible to conduct the entire study without periodically removing the subjects from the chamber for X-raying. Rohm and Haas Company's methyl methacrylate product, Plexiglas, proved most satisfactory. A portable X-ray machine (GE Model KX-12) was used. Subjects kneeled on a soft foam rubber mat shelf with their abdomens pressed against a bucky-diaphragm and cassette-holder (Liebel-Florsheim Company's portable model). The kneeling shelf was adjustable so that each subject's gastric shadow could be centered in reference to the X-ray cone and to the film which were fixed by the position of the window. A single wooden unit held both the bucky diaphragm and the adjustable kneeling shelf. This structure was placed in the chamber lock (Illustration No. 1). In addition, a light-proof wooden closet which could be placed within the chamber and in which X-ray films

could be developed made it possible to ascertain the status of the meal in the stomach only 10 minutes after each filming (Illustration No. 2).

The susceptibility of gastric motility to sundry evanescent and nebulous environmental influences has become increasingly manifest since the work of Pavlov and this understanding has especially expanded under the impetus of recent psychosomatic investigations. Thus, the rapidity of gastric evacuation varies quite widely from day to day just as the environmental forces to which it is subject vary from day to day. While this fact militates in favor of many replications at each level, the danger of radiation exposure and the difficulty of obtaining subjects precluded many replications. Procuring volunteers at a busy Air Field for prolonged experimentation is beset with many obstacles. A study involving fewer reruns less readily discourages subjects. Regarding the radiation hazard this admonition of the International Commission on Radiation Protection[3] was constantly borne in mind; "While the values proposed for maximum permissible exposures are such as to involve a risk that is small compared to the hazards of life, nevertheless, in view of the unsatisfactory nature of much of the evidence on which our judgments must be based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposures to all types of ionizing radiation to the lowest possible level." Several steps were taken to minimize subject exposure. Concentric lead-ring diaphragms were applied to the tube cone in such a manner as to shield all of the subject's body except the part necessary for the roentgen visualization of the stomach. In addition, an aluminum sheet, 0.063 inches thick, was placed over the tube. Together with the plexiglas window the aluminum sheet constituted a filter that eliminated the weak rays that might be absorbed by the subject and fail to record an impression on the film. The stronger rays were not eliminated; they are more valuable in exposing the film and, also, less dangerous biologically. Only absorbed rays are harmful.

By these means it became possible to reduce subject exposure to 0.50 roentgens per film as measured with Victoreen Instrument Company's Pencil Dosimeter. Since each emptying-time run required several films, usually about six, each run would involve an exposure of approximately 3.0 r (i.e., six films x 0.50 r). In four such runs (two at ground level and two at altitude) a subject would receive 4 x 3.0 or a grand total of 12 r. This radiation was spread over a four-week period and compares favorably with the roentgens experienced in a routine hospital gastrointestinal fluoroscopy. It also compares favorably with the recommendation of the International Commission for Radiation Protection[3]. The Commission suggests 0.3 r as the maximum permissible weekly dosage for personnel in radiological occupations. Since 0.3 r x 40 weeks = 12.0 r, if the subjects of this study received no other radiation for a forty-week period (and they probably would not) their accumulated exposure would be within the Commission's recommended ceiling.

The end point of gastric evacuation was determined by serial roentgenograms repeated until the stomach appeared free of barium. The midpoint of the time interval between the last film revealing barium still in the stomach and the first film revealing no barium was selected as the experimental end point. The negligible amount of barium occasionally adhering to the gastric mucosa after apparent emptying was ignored. Since

the serial roentgenograms were repeated every 20 minutes, this end point was, at best, an approximation to the nearest 10 minutes. Similarly the midpoint of the ingestion period was selected as the zero time or the beginning time of gastric emptying. It was found that, if unhurried, subjects required approximately 10 minutes to consume the test meal and that each subject usually duplicated his own consumption time on subsequent runs. Thus, any deviation from an ideally true beginning time would be quantitatively similar for both ground and altitude runs and in a comparison of the two the deviations would cancel each other out.

In 1947 Annegers and Ivy[4] introduced a simplified roentgenographic method for determining the rapidity of gastric emptying. It can be pursued adequately with only two or three films exposed at preselected intervals of time. The stomach shadow of an initial post-cibum film is determined with a planimeter. This area is defined as 100% and the gastric shadow areas of subsequent films are similarly measured and expressed proportionally. This method is predicated on the consistency of an individual's gastric configuration and necessitates, of course, scrupulous maintenance of the geometry (i.e., alignment) of the roentgen-ray machine, the film and the subject. This exacting requirement of the Annegers-Ivy Method is offset by two advantages:

1. Each volunteer is subjected to less radiation since fewer exposures are required.

2. Less time-consuming experiments are possible; the longer procedure of awaiting complete gastric evacuation is trying for both subject and observer.

In the course of determining the final emptying time a few experiments were so conducted that the applicability of the Annegers-Ivy Method could be simultaneously ascertained. Duplicate runs on each subject at each level permitted a comparison of the gastric areas of the same individual under the same conditions, at different times. The closeness of such duplicates would be an index of the reliability of the method.

SECTION II - PROCEDURES

Volunteers, recruited from the various laboratories at Wright Air Development Center, were carefully indoctrinated as to the goals of this study. The importance of their following the directions for pretest fasting was explained. Particularly emphasized was the necessity of their reporting emotional stresses or bodily disabilities that might jeopardize the validity of the experiment. Fortunately, the majority of the subjects became quite enthused with the project and as a group they were most cooperative. Several, however, dropped out before all four runs had been completed. Some because of transfer from the field; some from lack of interest and boredom with the lengthy procedure; and some at the insistence of their job supervisors who refused to countenance further absence from work.

Subjects having fasted overnight reported to the chamber at 0800. Their street trousers were replaced by beltless, buttonless, operating-room pants. They then entered the chamber (a six-man walk-in type with lock compartment), seated themselves and relaxed. Magazines and newspapers were available and music was piped in via the chamber's intercommunication system. For runs at altitude the chamber was decompressed at this time to the desired level (15,000 ft. or 12,500 ft. equivalent). During the subsequent twenty-minute period of relaxation and equilibration the standard test meal was prepared.

Two test meals were employed in these studies. The two were entirely alike in constituents and differed only in relative quantities. The first two subjects were fed the larger meal of 337 grams; the other five subjects received the smaller meal of 196 grams. This reduction (42% by weight) was undertaken in an attempt to shorten the length of each run. It became readily feasible when it was found necessary to alter the selected experimental altitude which will be explained below. The decrease in food volume, however, proved only slightly effective. Van Liere, Sleeth and Northrup[5], in 1937, similarly found that even doubling the size of a meal only prolonged the emptying time 17%.

The subjects who were studied at 15,000 feet and at ground level were fed the following test meal:

Barium Sulfate	40 gms
Chopped Ham & Eggs	100 gms
Fruit Cocktail	175 gms
Crackers	22 gms
Coffee	200 cc

All but the radiopaque salt are items from the USAF Food Packet, Individual, Combat, In-Flight, IF-2. The fruit cocktail and crackers were served at room temperature. The can of chopped ham and eggs was heated in boiling water for 20 minutes prior to opening. Then the contents were intimately mixed with the barium sulfate. The serving temperature of this mixture was uniformly about 110 to 120°F. It was found critically important that the barium salt be nicely blended into the ham and eggs so that large particles of unpalatable chalk would not be readily detected. A chemically simple barium sulfate product proved preferable to those specifically prepared for gastrointestinal work. These latter compounds usually contain agar that permits the barium to more readily adhere to ulcer niches, thereby, facilitating the radiological diagnosis. In the current study it was desirable that the barium leave the stomach with the food chyme and not lag behind.

The subjects who were studied at 12,500 feet and at ground level were fed the following amounts of the same food constituents prepared in a like manner:

Barium Sulfate	30 gms
Chopped Ham & Eggs	75 gms
Fruit Cocktail	75 gms
Crackers	11 gms
Coffee	200 cc

At the end of the twenty-minute period of equilibration and relaxation the prepared test meal was carried into the chamber on an attractive blue tray (Illustration No. 3). An intermediary lock stage, of course, was used in altitude runs. No coercion was employed to have the food consumed in a fixed predetermined period of time. Meticulous care was taken in this regard to protect the subject from disquieting stresses. As indicated above the self-selected ingestion period was usually about 10 minutes and the midpoint was chosen as the zero time of the experiment.

During the several hours after eating the subjects remained seated at rest. The environment was kept comfortably cool by means of the cooling coils in the chamber. The air was constantly refreshed by means of the chamber's efficient ventilating system that functioned throughout both ground and altitude runs. Magazines and newspapers were available for diversion. Likewise, radio entertainment was piped into the room and playing cards were provided (Illustration No. 4). At altitude most subjects displayed periodic respirations which produced no subjective discomfort and of which they were apparently unaware. Also, they found themselves inclined to sleep. More then momentary dozing was prohibited. Throughout, the experiment was conducted with an eye to field conditions. Activities that seemed consonant with field activities were permitted; those that did not, were discouraged. Thus, sugar was allowed with coffee and smoking was permitted on the stipulation that the same amount of sugar and the same number of cigarettes would be repeated on each run.

During the ground level runs the chamber door was kept closed and exactly the same ritual of procedures was followed as at altitude. Initially it was hoped that this might prevent subjects from determining whether they were engaged in an altitude or in a ground level run. This notion, however, was quickly dispelled. Subjects readily differentiated 12,500 feet or more from ground level by the clicking of their eardrums with ascent and by the relatively poor sound-conducting qualities of the less dense air at altitude.

Serial roentgenograms were begun about the third hour of the run or later depending upon the results previously obtained with the particular subject. These serial films were repeated every 15 to 20 minutes until the stomach appeared empty. For each film the subject merely walked out to the chamber lock and kneeled in position on the specially constructed kneeling-chair and bucky-diaphragm holder described above (Illustration No. 1). One of us (E. S.) was in the chamber and coordinated the subject's respirations with the exposing of the film. The subject was directed to hold his breath in deep expiration and, simultaneously, via the chamber's intercommunication system this information was conveyed outside of the chamber to another one of us (M. M. J.) who then activated the X-ray machine (Illustration No. 5). Exposures were made at 1/20th of a second, with 100 milliamperes current and at about 80 kilovolts. The target-film distance was 45 inches. The precise number of kilovolts employed was varied according to the bodily configuration of the subject. Immediately after each exposure the film was developed in the wooden darkroom within the chamber proper (Illustration No. 2). This usually required no more than 10 minutes.

As indicated above the first few subjects were also X-rayed during the first three hours of the experiment. This was in accord with the Annegers-Ivy Method and the films were taken at precisely five minutes post-cibum, one hour post-cibum, and two hours post-cibum.

SECTION III - RESULTS

Seven volunteers completed a total of four runs, that is, two at ground level and two at altitude. The findings are tabulated in Table 1. Note that all four meals consumed by a given subject were identical. Each horizontal row, therefore, is a record of the responses of the one subject, first at ground level, and then at altitude, to the same meal. The difference tabulated in the far right-hand column is the difference in the average time required for this meal to leave the subject's stomach at altitude compared with the average time required for the same meal to leave his stomach at ground level. In each column labeled "Deviation" is recorded the difference between the average emptying time and the two duplicates from which this average was computed. The magnitude of this deviation reflects the variability of an individual's gastric motility from time to time. Although several instances of marked fluctuation in gastric emptying time are noted, the average percent deviation of the entire study does not exceed 10%. It will be noted that there is no marked difference between the average emptying time at altitude and that at ground level. Except for JW and HH, the difference between the average emptying time at ground level and that at altitude is smaller than the exactness limit of the method which at best is ± 10 minutes. The time of gastric emptying, it will be recalled, was determined to the nearest ten-minute interval. The application of the F test[6] to the data discloses an F value of 1.5 which is below the 5.99 check value of the 5% significance level and thereby indicates no significant difference between the time of emptying at ground and that at altitude.

In Table II are tabulated the results of studies pursuant to the technique of Annegers and Ivy. Occasional large differences between duplicates are noted. Also, there appears to be poor correlation between the two rates of gastric emptying, that is, between the one determined by the percentage decrement in surface area and that determined by repeated roentgenograms till the stomach appeared empty. In some instances there appeared to be an actual inversion. For instance, when subject GB emptied at altitude in four hours 16 minutes the Annegers-Ivy Method indicated 35.2% of the barium meal remaining in the stomach after two hours; on rerun the two-hour film indicated 68.5% of the meal still in the stomach and yet the final emptying time was only three hours 30 minutes. This poor correlation between the two clearly demonstrated that the Anneger-Ivy Method could not reliably reflect the final emptying time. It is conceivable that the planimeter type of study indicates the rapidity of gastric emptying during the initial hours of evacuation (when large changes of area take place during short periods of time) and that this need not collate with the rapidity of

TABLE I

GASTRIC EMPTYING TIME AT GROUND LEVEL AND AT ALTITUDE

SUBJECT	GROUND LEVEL EMPTYING TIME							15,000 FOOT EMPTYING TIME							
	First Run		Second Run		Average		Deviation	First Run		Second Run		Average		Deviation	Difference
	Hr	Min	Hr	Min	Hr	Min	Min	Hr	Min	Hr	Min	Hr	Min	Min	Min
GB	3	58	3	57	3	58	01	4	16	3	30	3	53	23	-05
VW	4	04	3	30	3	47	17	4	07	3	45	3	56	11	+09
Average					3	53	09					3	55	17	
	Percent average deviation 3.8%							Percent average deviation 7.2%							

SUBJECT	GROUND LEVEL EMPTYING TIME							12,500 FOOT EMPTYING TIME							
	First Run		Second Run		Average		Deviation	First Run		Second Run		Average		Deviation	Difference
	Hr	Min	Hr	Min	Hr	Min	Min	Hr	Min	Hr	Min	Hr	Min	Min	Min
JW	3	35	4	14	3	55	20	3	24	2	51	3	08	17	-47
MD	4	55	6	07	5	31	36	6	45	4	28	5	37	69	+06
HH	4	55	4	20	4	38	18	3	31	4	21	3	56	25	-42
BC	4	29	3	26	3	58	32	3	59	3	51	3	55	04	-03
DR	6	06	5	15	5	41	26	5	42	5	19	5	31	12	-10
Average					4	45	26					4	25	25	
	Percent average deviation 9.1%							Percent average deviation 9.4%							

$F = 1.5$ which is < 5.99, the check value of the 5% significance level.

TABLE II

RADIOPAQUE GASTRIC SHADOW AREAS

Subject	Run Type & Number	Planimeter Measurements 5 Minute	1 Hour	2 Hour	Expressed as % Remaining 5 Minute	1 Hour	2 Hour	Serial Roentgenogram Emptying Times From Table I Hr	Min
		cm^2	cm^2	cm^2	%	%	%	Hr	Min
GB	Ground Level #1	-	95.8	34.5	100	149.5	53.8	3	58
	Ground Level #2	64.1	89.0	38.8	100	138.8	60.5	3	57
	15,000 Feet #1	67.0	90.6	23.6	100	135.2	35.2	4	16
	15,000 Feet #2	70.7	-	48.4	100	-	68.5	3	30
VW	Ground Level #1	92.1	58.5	25.9	100	63.5	28.1	4	04
	Ground Level #2	87.8	61.0	17.4	100	69.5	19.8	3	30
	15,000 Feet #1	108.6	47.5	18.4	100	43.7	16.9	4	07
	15,000 Feet #2	80.0	47.7	23.5	100	59.6	29.4	3	45

total (or final) emptying. Henschel, Keys, Sturgeon, and Taylor[7] similarily found poor correlation between final emptying time and gastric motility as indicated by such decreases in two-dimensional shadow areas. They stated that: "It is apparent that in individual cases it would be impossible to predict satisfactorily the final emptying time from the motility rate during the first few minutes of gastric emptying." In the study reported here interest was focused on the possible prolongation of final gastric emptying as a result of altitude with the view to applying such information to the development of an in-flight feeding program for the United States Air Force. For this purpose the so-called initial gastric motility was not considered as reliable a guide as the more important final emptying time and so the Annegers-Ivy Method was discarded. It must be noted that the projection of a three-dimensional volume onto a two-dimensional surface requires rigid maintenance of the geometry of the X-ray tube, the subject, and the film which was probably not satisfactorily achieved by even the most careful use of guide lines painted on the floor. Without a floor-fixed machine, and floor-fixed film holder, which were infeasible in this chamber, one cannot do justice to the method of Annegers and Ivy.

SECTION IV - DISCUSSION

Perhaps the most salient impression gleaned from the material presented is the lability of the human gastric process. This was anticipated and psychogenic factors were foreseen as potentially responsible. To minimize unfavorable psychological stresses a vigorous program of preventive psychology had been undertaken as described above. The day prior to his first run each subject was taken to the chamber and the nature and ultimate goal of the experiment explained. Effort was made to have him witness another subject in the chamber and an experiment in progress. It was hoped that this would greatly diminish his potential apprehension. Throughout the experiment a spirit of pleasantry and joviality in a job being well done was maintained. Apparently these efforts were insufficient. It is obviously impossible to control a human subject's total environment or to limit the free play of his intellectual ruminations.

Presuming that the environmental factors are the ones responsible for the fluctuations between duplicates and aware that most extrinsic factors act to retard gastric evacuation and that few, if any, act to hasten it, one would anticipate that with greater familiarity with the test conditions (chamber, altitude and barium ingestion), the subject's apprehension would diminish and his stomach empty more quickly. This proved to be the case in 11 of 14 instances, which is an 80% confirmation. The remaining 20% well might be attributed to the superimposition of the gastric consequences of such nonexperimental environmental factors as family altercations or trying morning traffic jams. The subjects could not be shielded from these daily strains. This 80% confirmation is tabulated in Table III which is merely an analytical breakdown of the information in Table I. In it the length of the second emptying time at each level is compared with the length of the first run. In Table I the first run of each pair has been recorded in the left-hand column, although altitude and ground runs were conducted in a

TABLE III

COMPARATIVE LENGTH OF EACH SECOND DUPLICATE TO THE CORRESPONDING FIRST DUPLICATE OF TABLE I

	Ground Level Studies	15,000 Feet Studies
GB	S	S
VW	S	S

	Ground Level Studies	12,500 Feet Studies
JW	L	S
MD	L	S
HH	S	L
BC	S	S
DR	S	S

Note:

S - Second run shorter than first.

L - Second run longer than first.

random sequence. No rigid sequential pattern of altitude and ground level runs was pursued; several of the possible permutations of the four runs were tried. Table III, then, lends credence to the view that it was the subject's apprehension at being a "human guinea pig" that was responsible for the prolongation of the initial runs and for some of the deviation between duplicates. The experience of Van Liere and Sleeth[8] has been similar and in 1940 they observed that within a control group of 37 people there was a rather consistently "... wide individual variation; the shortest time of any individual, however, remains remarkable constant from day to day."

The finding of this study that moderate altitude effects no significant alteration in the rapidity of human gastric emptying appears in conflict with the earlier conclusion of the West Virginia group[2]. The experimental conditions, however, were somewhat different. The earlier work was conducted with equipment that necessitated removal of the subject periodically from the chamber for fluoroscopy. It is quite conceivable that the disturbing experience of repeated ascent and descent played a crucial role in causing gastric delay. The study herein reported was conducted with facilities which permitted maintenance of the subject at the selected altitude throughout each run.

Caution is advised in applying the results of this study to everyday aviation. When observed at altitude the subjects were equilibrated at the altitude level for only 20 minutes before being offered the test meal. What might have occurred if the subjects had been fed after more than four to six hours at altitude remains undetermined and worthy of investigation. Everyday in-flight eating is customarily a mid-flight occurrence.

USAF policy requires the use of supplementary oxygen at levels above 10,000 feet. Originally this applied to the ambient altitude of non-pressurized aircraft, but the dictum has been extended to refer also to the cabin equivalent of pressurized aircraft. The chosen experimental altitudes, therefore, of 12,500 and 15,000 feet might appear odd. Their selection, however, was not capricious and was dictated by a desire to ascertain the function of the gastrointestinal tract at the lower levels, i.e., below the 10,000 ft. ceiling. Aware of the resiliency of the human organism and its ability to compensate quite adequately in the presence of noxious forces it was deemed advisable to place the subjects on a severe test in order to fatigue possible compensatory mechanisms and unmask the true inclination. The initially selected level of 15,000 feet, however, proved too strenuous for most subjects. Within the first few hours subjects paled and drooped. One almost fainted. Nausea was occasionally experienced and in the evening after one run vomiting occurred. Nevertheless, the two subjects studied at 15,000 feet experienced no prolongation in gastric emptying (see Table I). It became necessary, however, to reduce the experimental altitude level and 12,500 feet was tried. This proved much less taxing. There were no instances of nausea or vomiting but all subjects continued to manifest periodic respirations and to feel quite ennervated towards the termination of each run. Thus, 12,500 feet seemed a sufficient stress but not so great as to dissuade volunteers or frighten observers. Since the occurrence of respiratory anomalies and syncope preceded the development of any significant alteration in stomach motility it would appear that the gastric mechanism is more resistant to moderate altitude than is the neuro-respiratory system.

Biophysically altitude has a dichotomous connotation. First, it implies a diminution in the partial pressure of oxygen, and second, a diminution in the total barometric pressure. In the study reported here differentiation of the possible biological effects of these two forces on the emptying time of the human stomach was not delineable. The two forces might act synergistically; they might act antagonistically; one or both might be without effect. It appears, however, that they do act antagonistically. The evidence for this is as follows. It is well accepted that deprived of oxygen, physiological processes eventually cease. Just prior to cessation they usually undergo a gradual abatement, although, this may be preceded by a transient hyperactive phase[9]. Significant hypoxia, therefore, should prolong gastric emptying time. On the other hand decreased barometric pressure would seem to provoke a hypermotility of the stomach. Steggerda, Clark and Danhof[10,11] of the University of Illinois have shown that the activity of the human gastrointestinal tract as indicated by intralumenal pressure recordings is more than doubled upon ascent to 12,000 feet. The presumed mechanism is the dilatation of each gas-containing visceral segment as a result of the diminished ambient pressure. The dilatation acts to stretch and, thereby, to stimulate the gastrointestinal musculature. It is parenthetically noted that the Illinois group also selected the 12,000 foot equivalent as the experimental level of study.

It thus appears possible that the diminished barometric pressure and the diminished oxygen pressure of altitude act antagonistically. Likewise, it appears entirely possible that in this study the critical factors of food volume, selected altitude, and the time at altitude before eating, were all such that a nice balance was achieved so that the gastric emptying time at altitude duplicated that observed at ground level. A significant alteration of any of the critical factors might well disturb the balance and yield somewhat different results.

SECTION V - SUMMARY

The effect of moderate altitude on the rapidity of gastric emptying has been studied in seven human subjects. The rapidity of gastric evacuation was determined by serial roentgenograms after the ingestion of a standard radiopaque meal. All subjects were observed twice at ground level and twice at moderate altitude. The decompression chamber employed was modified so that subjects could be roentgen-photographed without being removed from the chamber. No significant difference was found between the average emptying time at altitude and that at ground level.

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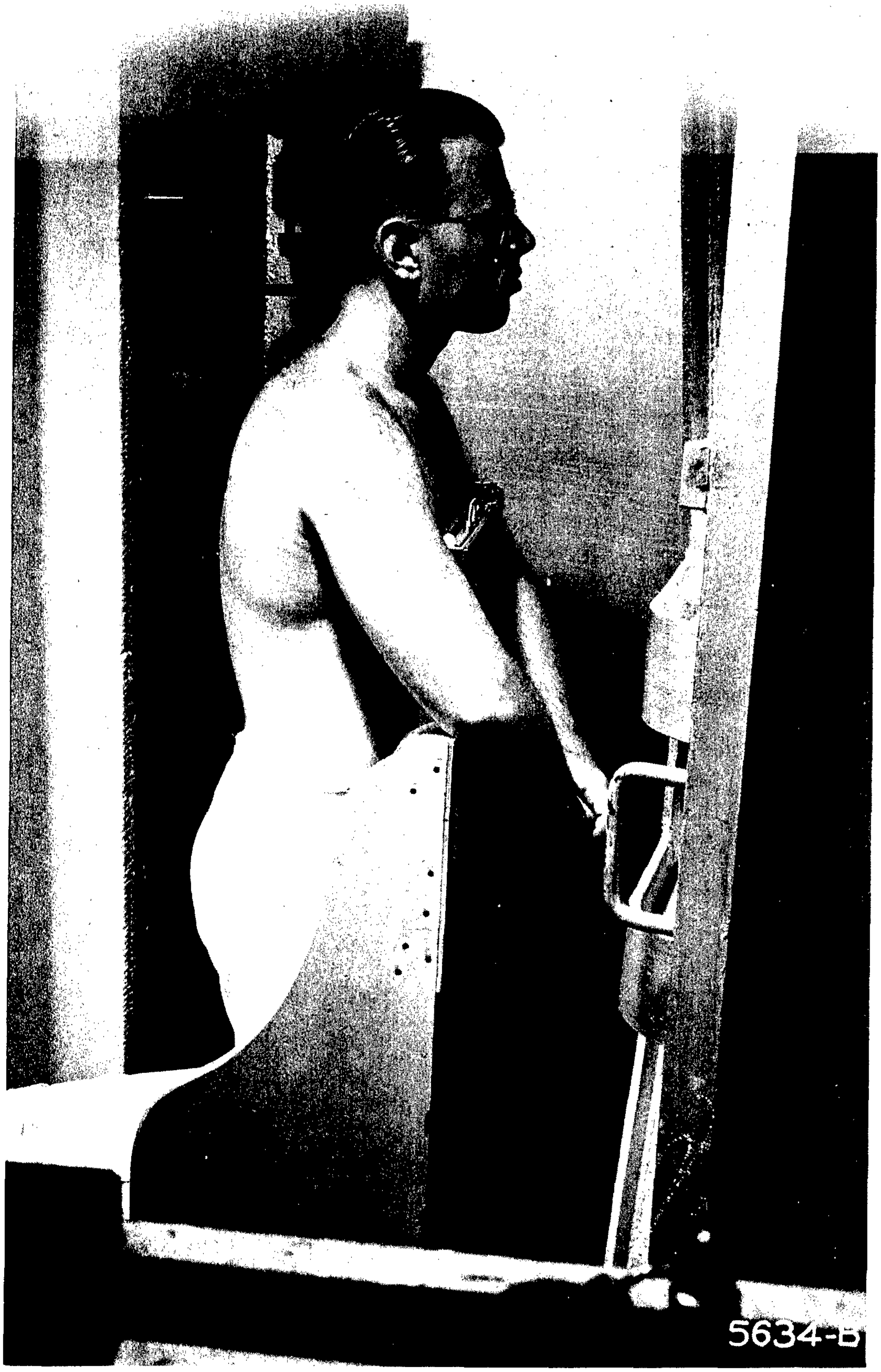

ILLUSTRATION NO. 1

Subject in position on kneeling-shelf with abdomen pressed against bucky-diaphragm. Entire unit is in the chamber lock.

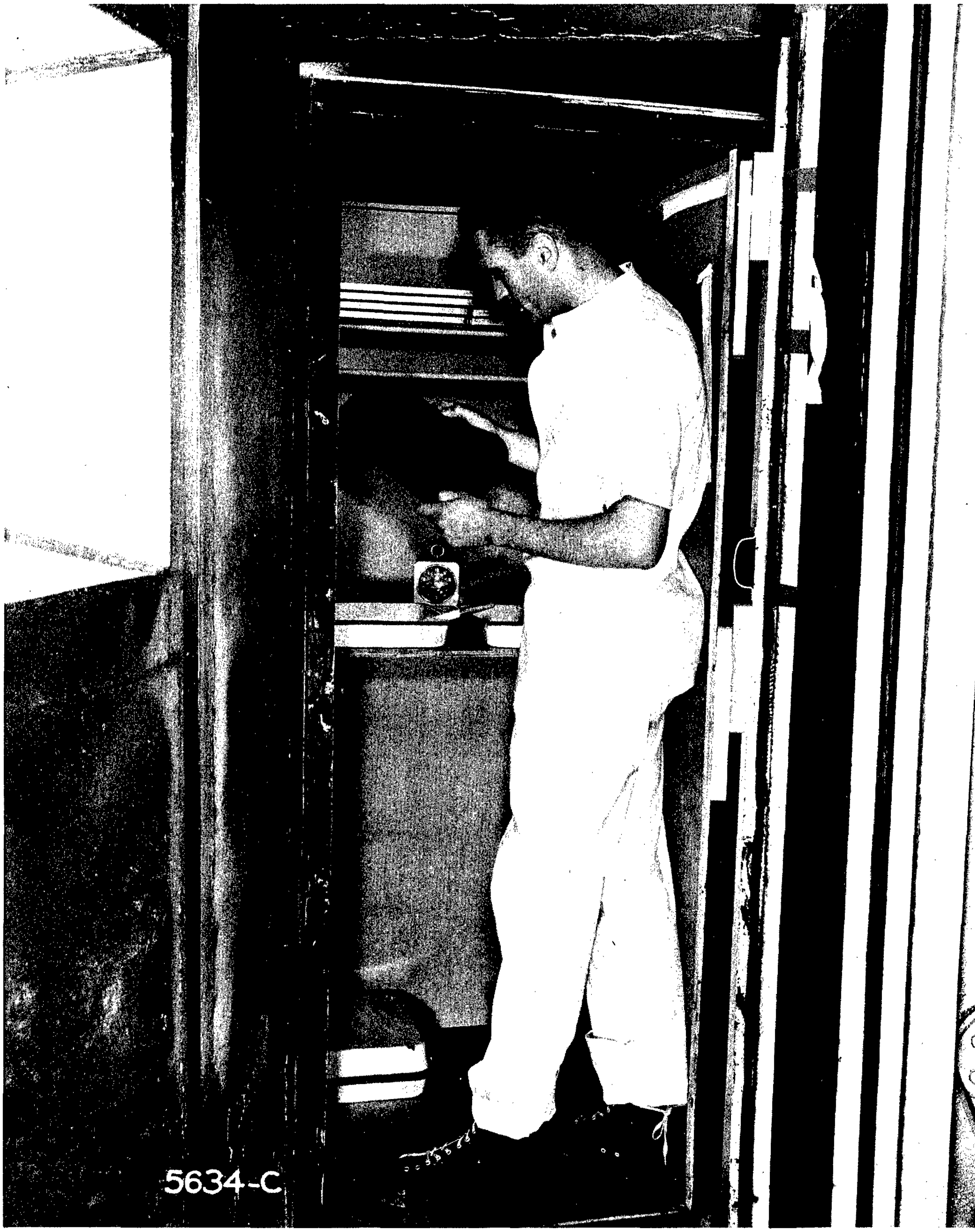

ILLUSTRATION NO. 2

Wooden darkroom in main compartment of decompression chamber

5634-E

ILLUSTRATION NO. 3

Test meal on tray as it was presented to subject. In foreground is Ham & Eggs-Barium mixture

ILLUSTRATION NO. 4

Two subjects relaxing during the early hours of a run. In the background right is the wooden darkroom

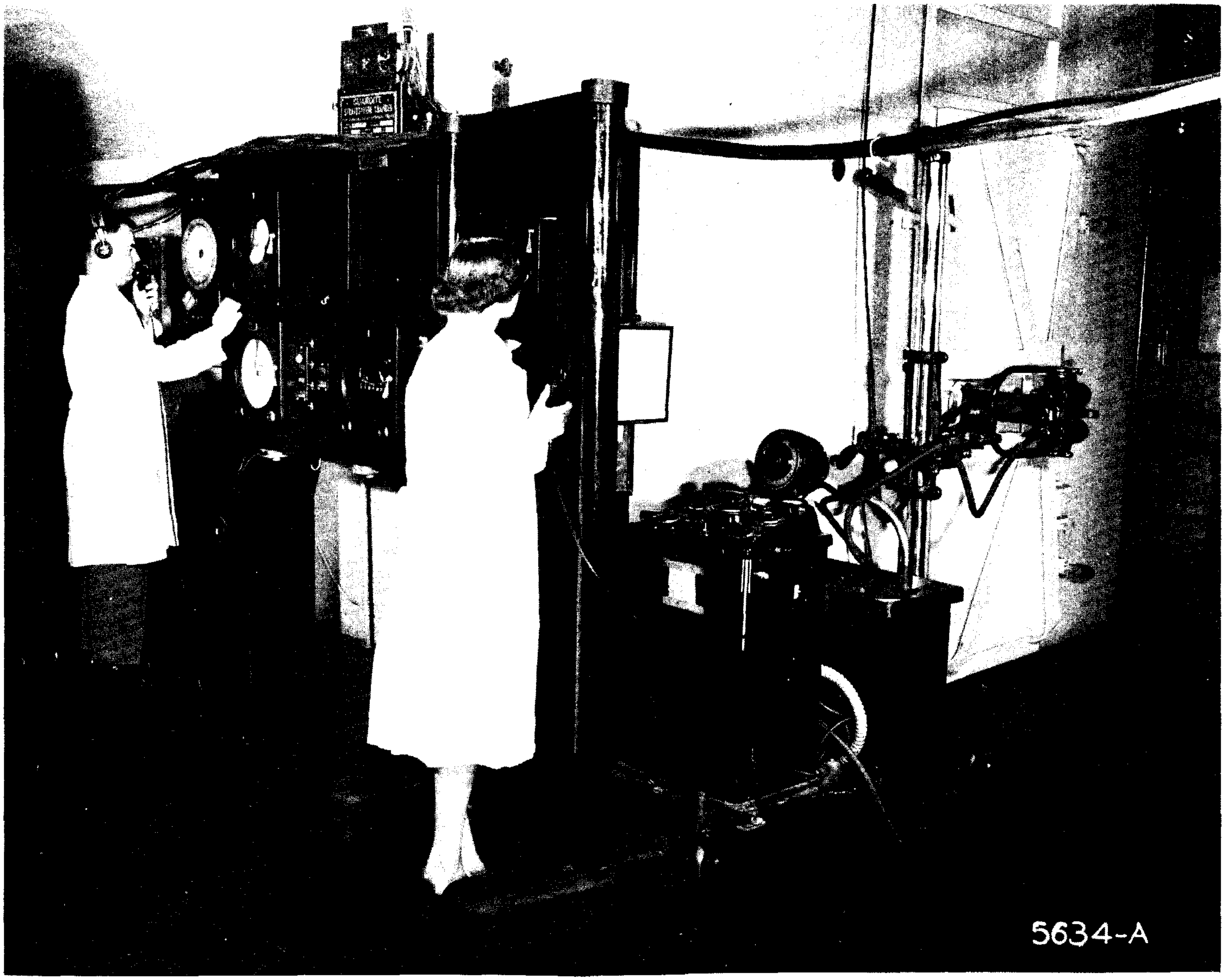

ILLUSTRATION NO. 5

The chamber exterior during a run. The chamber operator is on the left with intercom earphones and speaker. He is stabilizing the chamber altitude. On the right the X-ray equipment and X-ray operator are demonstrated. Note that the tube cone is flush against the plastic window.